US009330576B2

(12) **United States Patent**
Moran et al.

(10) **Patent No.: US 9,330,576 B2**
(45) **Date of Patent: *May 3, 2016**

(54) **VEHICLE CREW TRAINING SYSTEM**

(71) Applicant: **Raydon Corporation**, Port Orange, FL (US)

(72) Inventors: **Sean C. Moran**, Ormond Beach, FL (US); **Donnie R. Klein**, Ormond Beach, FL (US); **Mark D. Haack**, Ormond Beach, FL (US); **Sharon E. Lay**, Daytona Beach, FL (US); **Christopher J. Howard**, Daytona Beach, FL (US); **Michael J. Dineen**, Deltona, FL (US); **Jerry R. Hubbard**, Port Orange, FL (US); **William M. Araki**, Port Orange, FL (US)

(73) Assignee: **Raydon Corporation**, Port Orange, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/493,822**

(22) Filed: **Sep. 23, 2014**

(65) **Prior Publication Data**

US 2015/0056577 A1 Feb. 26, 2015

Related U.S. Application Data

(63) Continuation of application No. 11/055,708, filed on Feb. 11, 2005, now Pat. No. 8,864,496.

(51) **Int. Cl.**

F41A 33/00	(2006.01)
G09B 9/00	(2006.01)
G09B 9/04	(2006.01)

(52) **U.S. Cl.**
CPC ***G09B 9/003*** (2013.01); ***F41A 33/00*** (2013.01); ***G09B 9/04*** (2013.01)

(58) **Field of Classification Search**
CPC F41A 33/00
USPC 434/11
See application file for complete search history.

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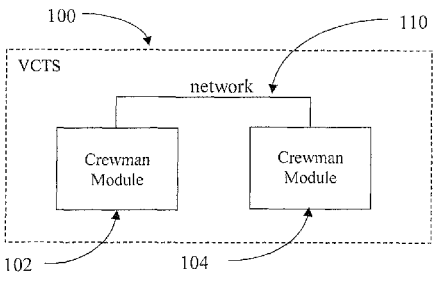
* cited by examiner

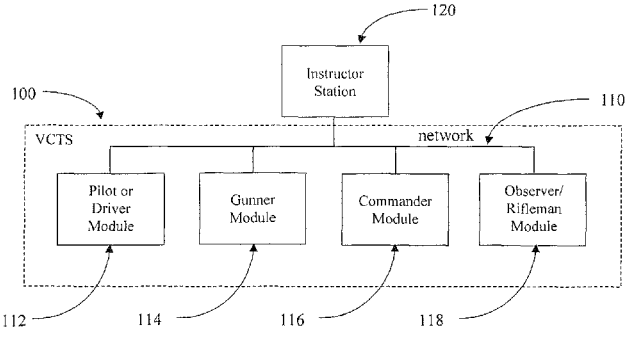
Primary Examiner — Kesha Frisby
(74) *Attorney, Agent, or Firm* — Miles & Stockbridge P.C.

(57) **ABSTRACT**

A computer based simulation system for virtual training for vehicle crews is disclosed. The vehicle crew training system (VCTS) simulates crew positions for different military vehicles. Two or more crewman modules are networked together to support a partial or full vehicle crew. The crewman modules are self-contained devices that are modular in hardware and software design, easily reconfigurable, and that require minimal facility space, allowing use in restricted environments such as trailers. The VCTS is modular at the crew position level; crewman modules are added or deleted as required to meet a particular training need. One of the crewman modules can be a gunner module, which provides an unrestricted view of the simulated environment to the gunner by means of a display and a simulated vehicle-mounted weapon.

15 Claims, 9 Drawing Sheets





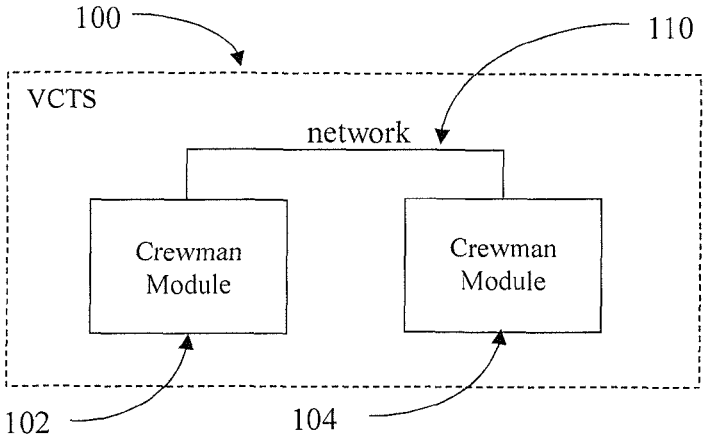

100
110
VCTS
network
Crewman Module
Crewman Module
102
104

FIG. 1A

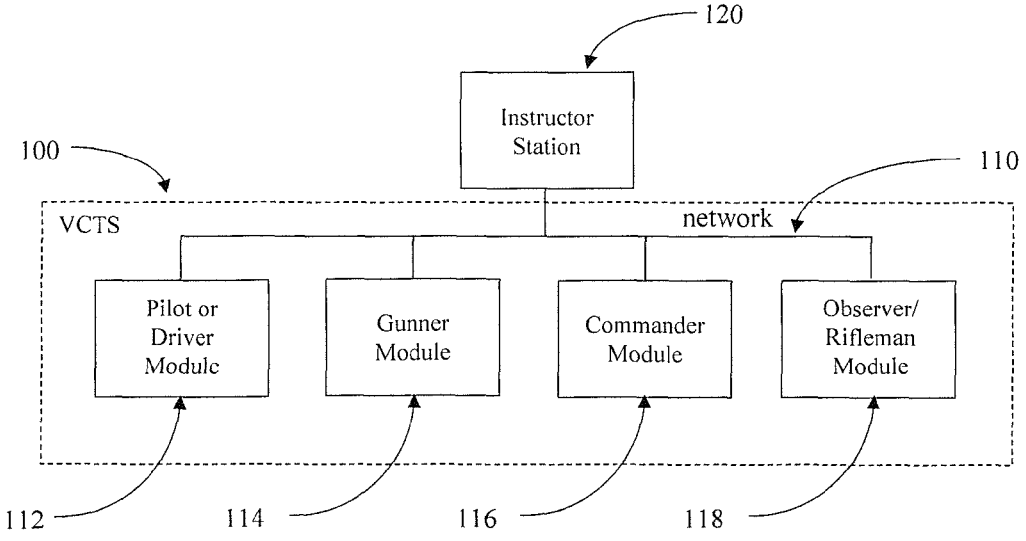

120
Instructor Station
100
110
VCTS
network
Pilot or Driver Module
Gunner Module
Commander Module
Observer/ Rifleman Module
112
114
116
118

FIG. 1B

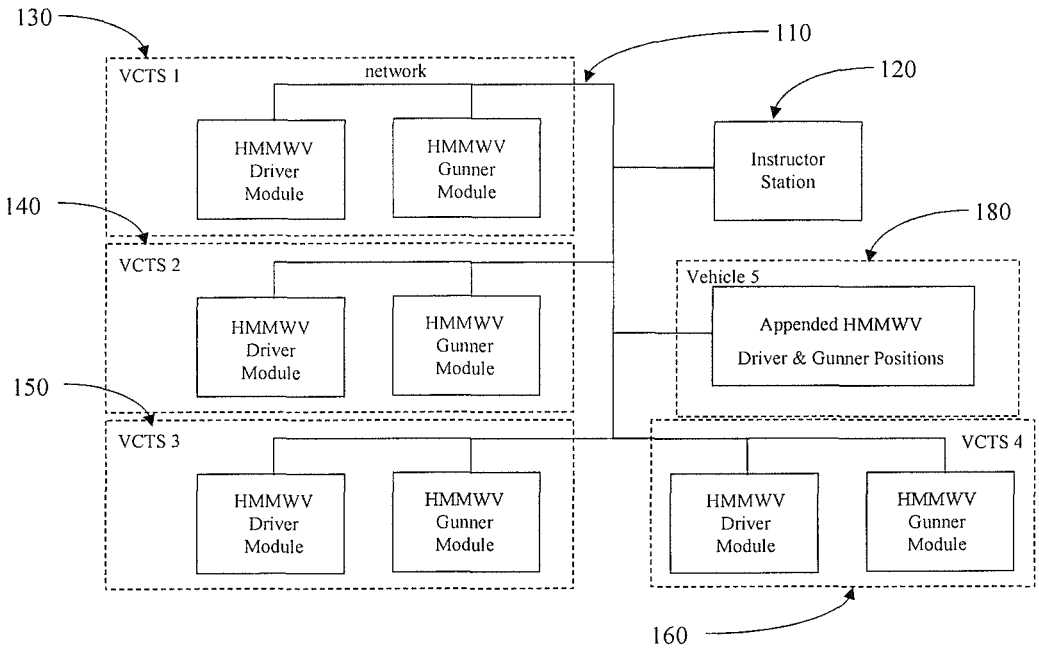

130
110
VCTS 1
network
120
HMMWV Driver Module
HMMWV Gunner Module
Instructor Station
140
180
VCTS 2
Vehicle 5
HMMWV Driver Module
HMMWV Gunner Module
Appended HMMWV Driver & Gunner Positions
150
VCTS 3
VCTS 4
HMMWV Driver Module
HMMWV Gunner Module
HMMWV Driver Module
HMMWV Gunner Module
160

FIG. 1C

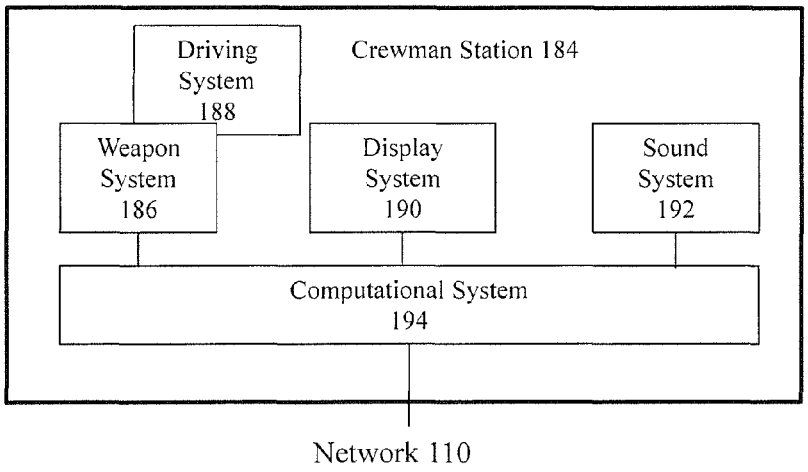


FIG. 2A

	Driver	Gunner	Commander & Observer/Rifleman
Weapon System	N/A	CAL .50 machine gun, MK-19 grenade launcher, M240B 7.62 mm machine gun, M249 Semi Automatic Weapon, TOW Missile	M-16 rifle, M-4 rifle; virtual dismount is supported
Driving System	Steering wheel, transmission selector, brake & accelerator pedals	N/A	N/A
Display System	LCD Panels	HMD	HMD
Sound System	Vehicle & weapon sounds	Vehicle & weapon sounds	Vehicle & weapon sounds
Computational System	PC	PC	PC

FIG. 2B

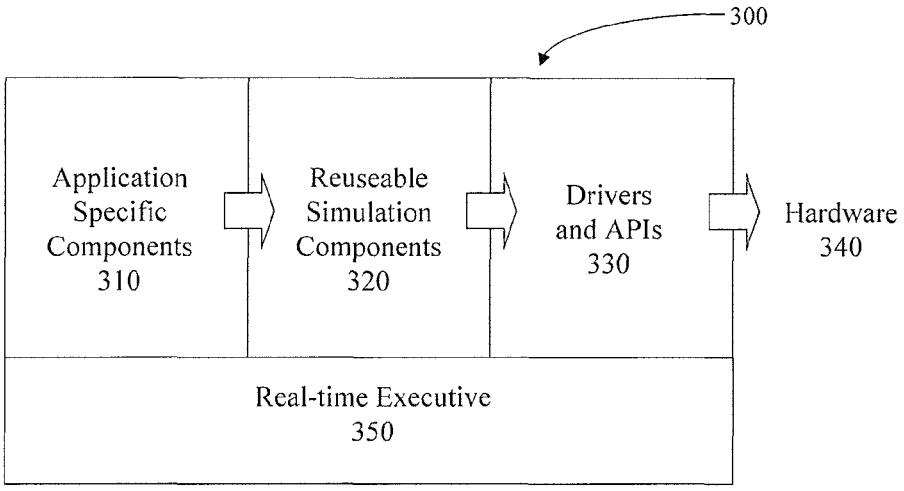

300
Application Specific Components 310
Reuseable Simulation Components 320
Drivers and APIs 330
Hardware 340
Real-time Executive 350

FIG. 3

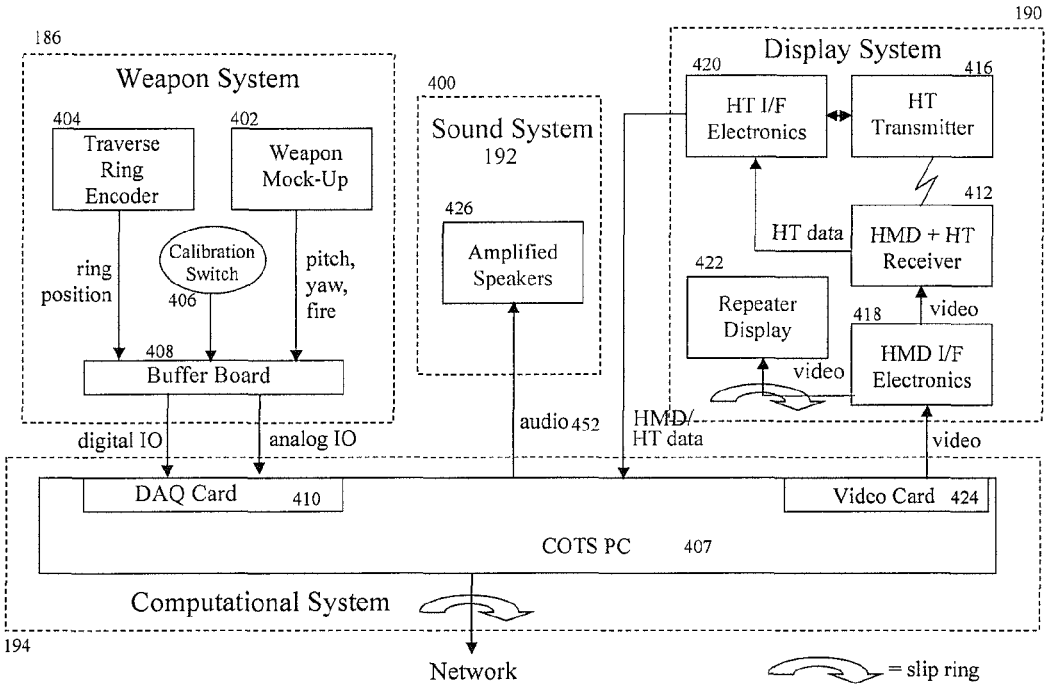

186
Weapon System
404
Traverse Ring Encoder
402
Weapon Mock-Up
ring position
Calibration Switch
406
pitch, yaw, fire
408
Buffer Board
digital IO
analog IO
400
Sound System 192
426
Amplified Speakers
audio 452
190
Display System
420
HT I/F Electronics
416
HT Transmitter
412
HT data
HMD + HT Receiver
422
Repeater Display
418
video
HMD I/F Electronics
video
HMD/ HT data
video
DAQ Card 410
Vidco Card 424
COTS PC 407
Computational System
194
Network
= slip ring

FIG. 4A

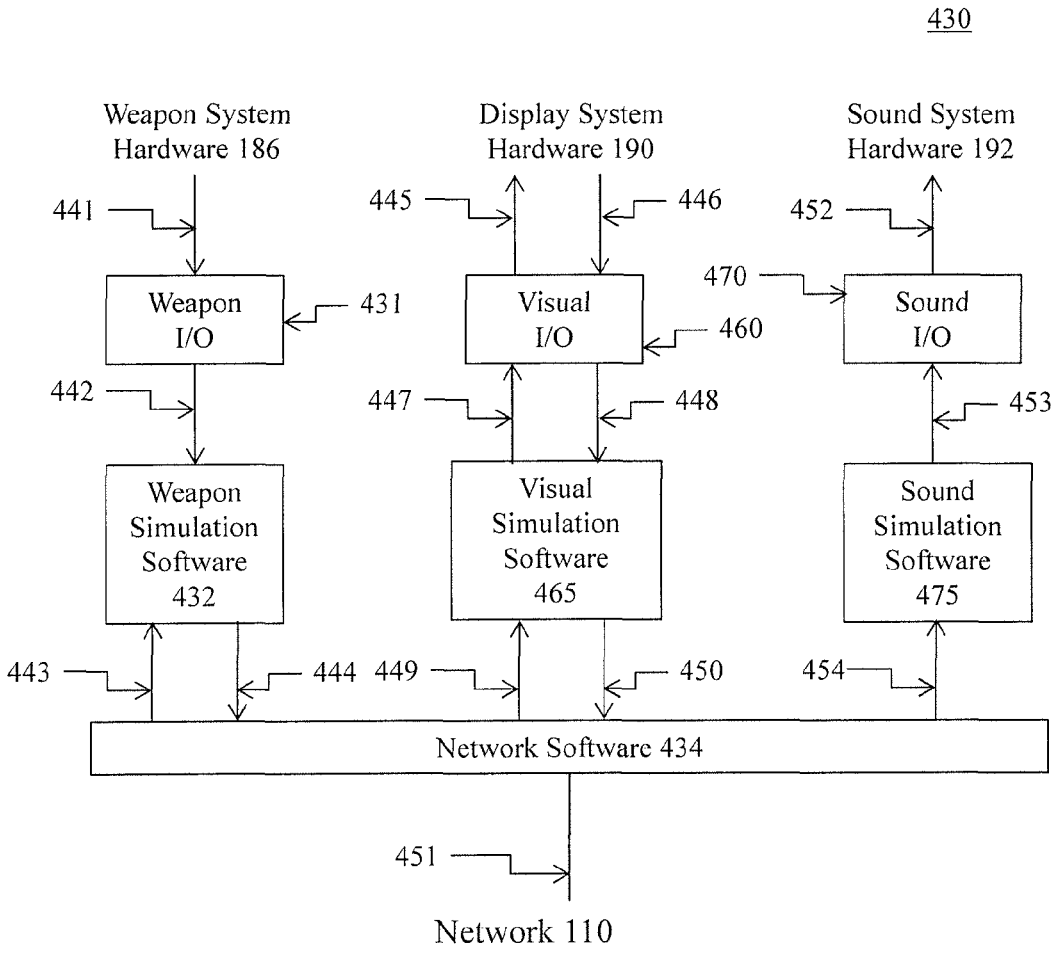

430
Weapon System Hardware 186
Display System Hardware 190
Sound System Hardware 192
441
445
446
452
Weapon I/O
431
Visual I/O
460
470
Sound I/O
442
447
448
453
Weapon Simulation Software 432
Visual Simulation Software 465
Sound Simulation Software 475
443
444
449
450
454
Network Software 434
451
Network 110

FIG. 4B

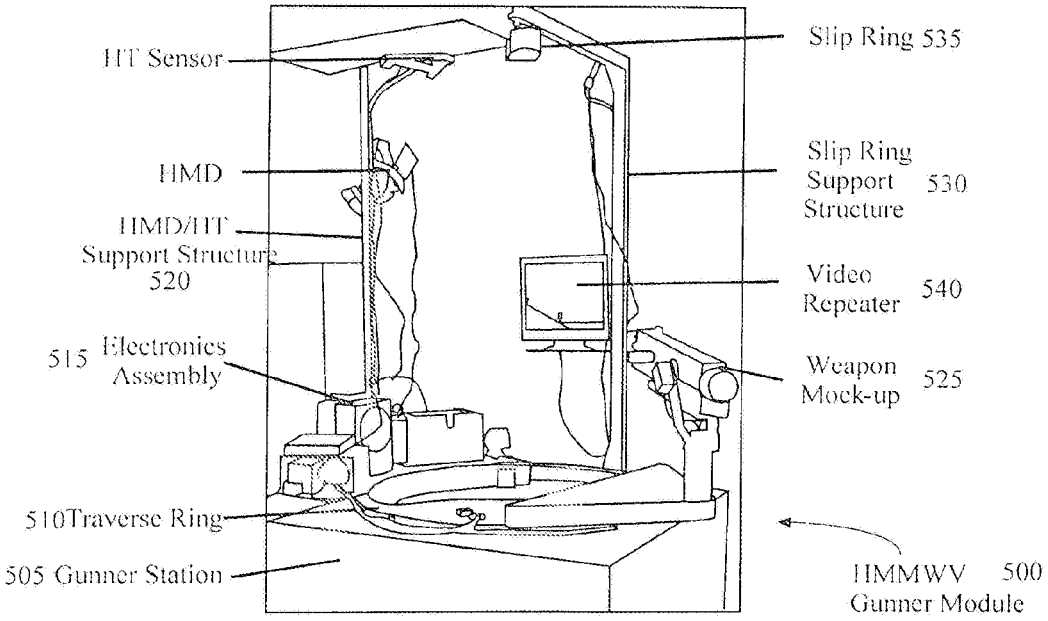

HT Sensor
Slip Ring 535
HMD
Slip Ring Support Structure 530
HMD/HT Support Structure 520
Video Repeater 540
515 Electronics Assembly
Weapon Mock-up 525
510Traverse Ring
505 Gunner Station
HMMWV 500 Gunner Module

FIG. 5A

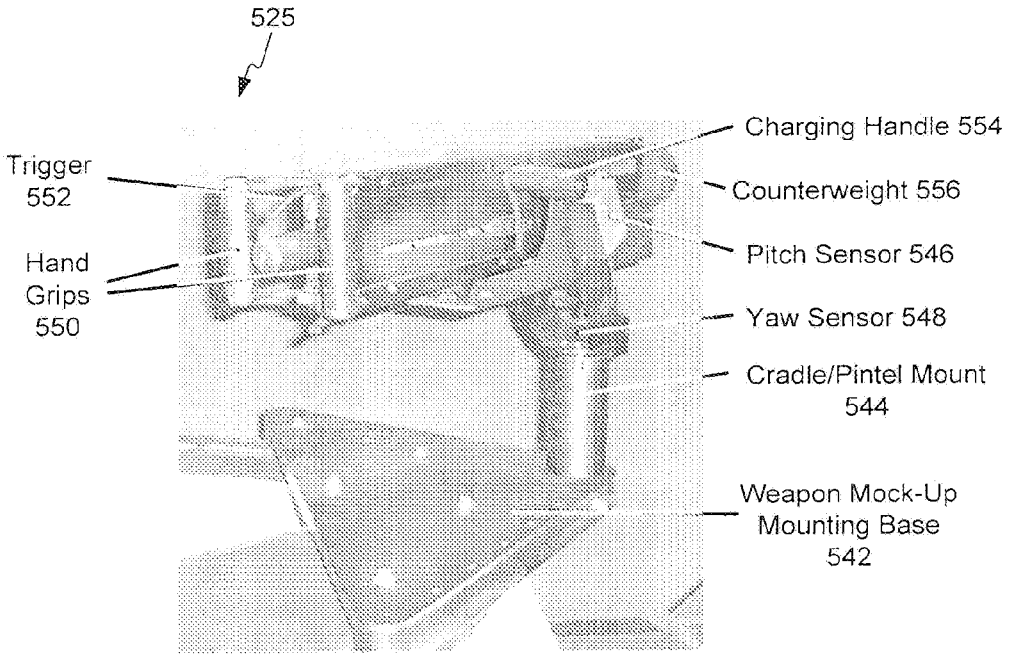

525
Charging Handle 554
Trigger 552
Counterweight 556
Pitch Sensor 546
Hand Grips 550
Yaw Sensor 548
Cradle/Pintel Mount 544
Weapon Mock-Up Mounting Base 542

FIG. 5B

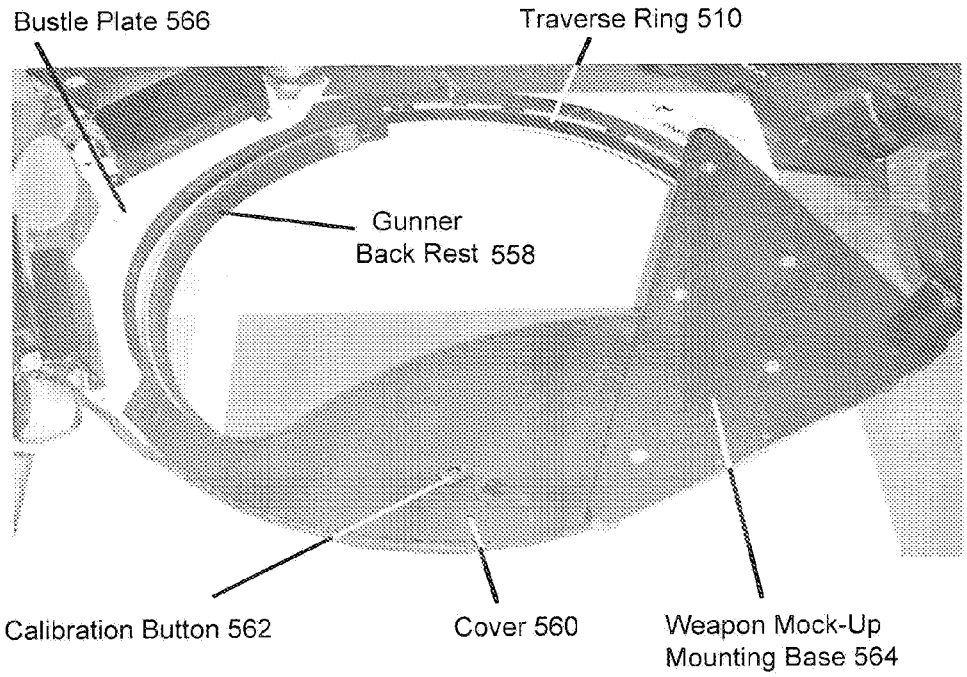

Bustle Plate 566
Traverse Ring 510
Gunner
Back Rest 558
Calibration Button 562
Cover 560
Weapon Mock-Up
Mounting Base 564

FIG. 5C

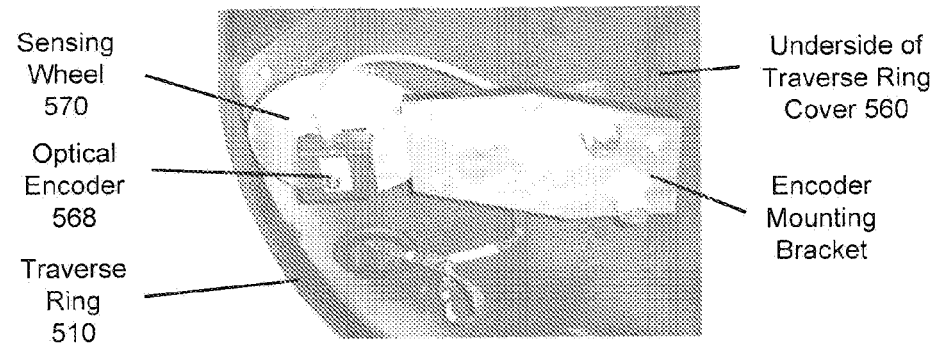

Sensing
Wheel
570
Optical
Encoder
568
Traverse
Ring
510
Underside of
Traverse Ring
Cover 560
Encoder
Mounting
Bracket

FIG. 5D

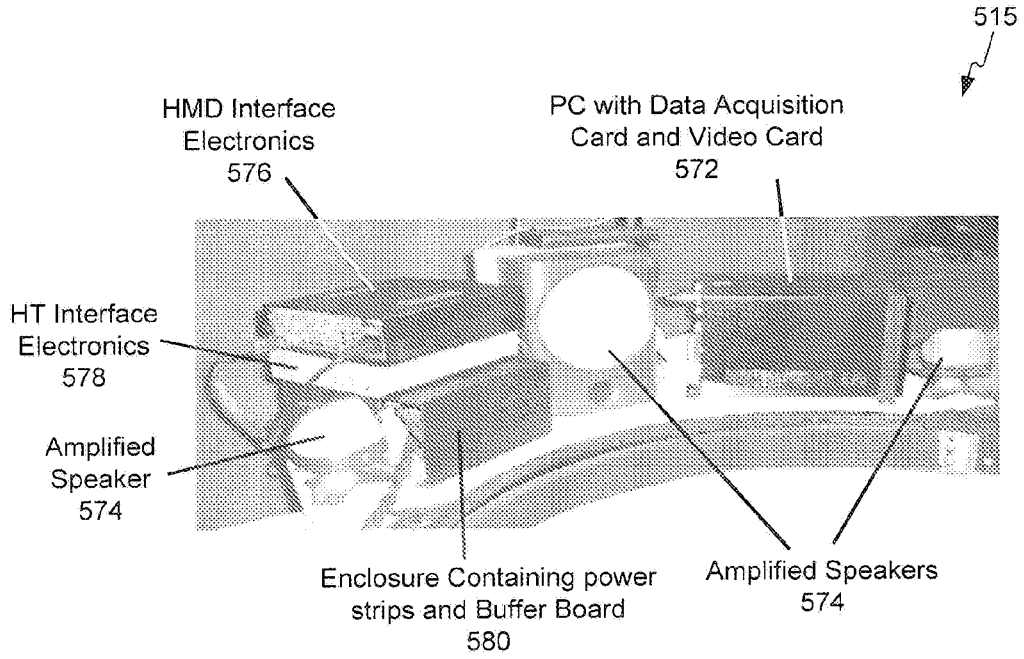

515
HMD Interface Electronics 576
PC with Data Acquisition Card and Video Card 572
HT Interface Electronics 578
Amplified Speaker 574
Enclosure Containing power strips and Buffer Board 580
Amplified Speakers 574

FIG. 5E

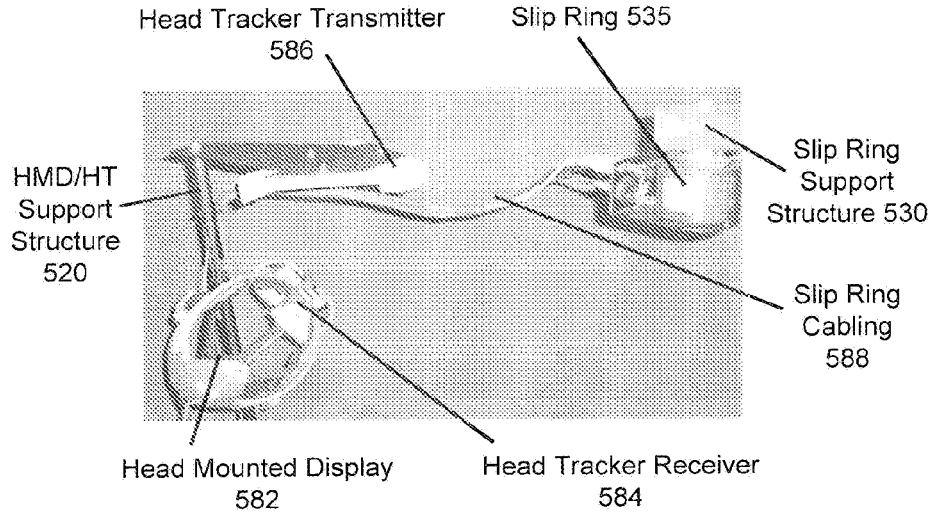

Head Tracker Transmitter 586
Slip Ring 535
HMD/HT Support Structure 520
Slip Ring Support Structure 530
Slip Ring Cabling 588
Head Mounted Display 582
Head Tracker Receiver 584

FIG. 5F

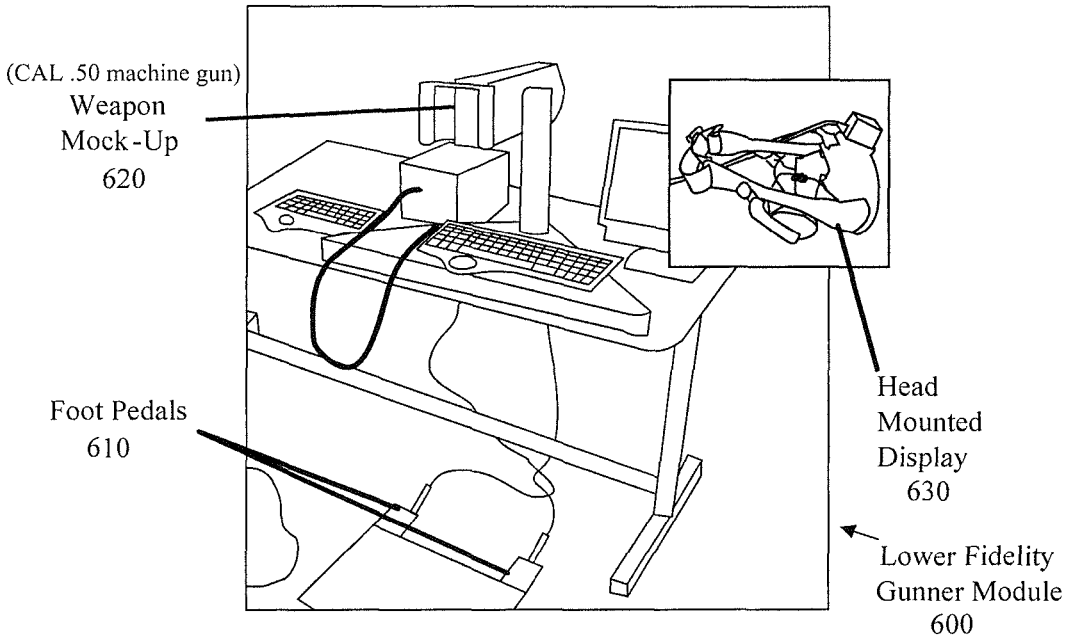

(CAL .50 machine gun)
Weapon
Mock-Up
620
Foot Pedals
610
Head
Mounted
Display
630
Lower Fidelity
Gunner Module
600

FIG. 6

VEHICLE CREW TRAINING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 11/055,708, filed Feb. 11, 2005 (issuing as U.S. Pat. No. 8,864,496), which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The invention pertains to training simulators.

BACKGROUND OF THE INVENTION

System Design

Historically, most virtual crew training has been accomplished with appended trainers or with crew station trainers. An appended trainer consists of equipment added to an actual (parked) combat vehicle such that the vehicle is used to train a full or partial crew in a virtual environment. Examples are Raydon's Abrams Appended Trainer (A-FIST XXI) and the Bradley Appended Trainer (AB-FIST). A crew station trainer includes a replica of a crew compartment of an actual vehicle. Examples are Raydon's M-COFT XXI and SIMNET XXI trainers for the Abrams tank and the Bradley fighting vehicle. The appended and crew station trainers typically provide higher fidelity and very little modularity. Here, "fidelity" refers to the physical and functional realism of the man-machine interface, specifically, the realism of the vehicle and/or weapon controls in terms of numbers of controls and control realism; the realism of visual imagery in terms of field of view, resolution, and scene content; and the realism of the physical crew position in terms of the human support structure. Further, these trainers tend to be purpose-built for either individual/crew training or for collective training, but not both.

More recently, desktop training systems have emerged that are capable of training individuals and crews of military combat vehicles with less fidelity but at a much lower cost than the appended and crew station trainers. However, these desktop systems are not modular and, like the higher fidelity appended and crew station trainers, tend to be purpose-built for either individual/crew training or for collective training, but not both.

Hence, there is a need for a virtual crew training system that is sufficiently flexible to allow both individual/crew training and collective training, is modular, and can provide any level of fidelity.

Gunner Module

Current simulators for mounted weapons training use video projection screens and a fixed mount weapon mockup. Taken together, this results in a limited field of view for the gunner, i.e., the gunner can only look and shoot at scenes depicted on the projection screen. Typically, these screens are limited to the forward direction only.

This approach also requires more space to implement, making it impractical to use in standard trailers or portable shelters. One instantiation of this approach was implemented by the U.S. government at the Mounted Warfare Testbed in Fort Knox, Kentucky. Another instantiation of this approach was implemented by Lockheed Martin for the government's Virtual Combat Convoy Trainer program, as documented in the Aug. 31, 2004 *Orlando Sentinel*. Hence, there is a need for a mounted-weapon training simulator module that has a relatively small physical footprint, yet provides realistic perspective, i.e., in all possible directions, for a trainee's view and aim.

SUMMARY OF THE INVENTION

System Design

The vehicle crew training system (VCTS) is a computer-based simulation system intended to serve the virtual training needs of military users. However, unlike other simulation systems, the VCTS is modular at the crew-position level; crewman modules are added or deleted as required to meet a particular training need. The VCTS provides virtual training for vehicle crew members. "Virtual training" refers to a mode of training in which the trainee is immersed in a simulated environment as a participating entity, and in which results of all actions occur in real-time based on cause and effect. This is also referred to as "real-time, man-in-the-loop simulation." The simulation system also supports virtual dismounting of a trainee, such that the trainee may virtually exit the virtual vehicle while maintaining the ability to interact with the virtual environment from the vantage point of a dismounted position. Three modes of virtual training are supported: individual training; crew training; and collective training with multiple vehicle crews. The VCTS is able to simulate crew positions for different military vehicles and their associated weapon systems. The VCTS comprises crewman modules networked together to support a partial or full vehicle crew. Moreover, not only is the VCTS modular, but each crewman module is itself modular. The crewman modules are self-contained devices that are modular in hardware and software design, and easily reconfigurable. In addition, the crewman modules occupy a minimal physical footprint.

One instantiation of the VCTS is a high mobility multipurpose wheeled vehicle (HMMWV) trainer developed by Raydon Corporation, of Daytona Beach, Fla. This system can be used for virtual combat convoy training in a simulated geographical environment. In an embodiment of the invention, the simulated environment corresponds to an actual urban or rural setting. Future VCTS variants include, but are not limited to, the heavy expanded mobility tactical truck (HEMTT), the standard cargo truck, and the five-ton tactical truck.

The VCTS consists of two or more crewman modules networked together. A typical set of crewman modules constituting a VCTS includes a driver module, a commander module, and a gunner module. Via a network, other devices, such as an instructor station and a simulated radio, may be integrated with the VCTS. Additional crewman modules may be added for other crew members, such as an observer/riflemen. Vehicle crew training systems may also be linked together to form groups of simulated vehicles, such as platoons of three or four vehicles, where each vehicle is configured with two or more crewman modules. Two instructor stations may be included in these larger embodiments to facilitate training simultaneously with the conduct of after-action reviews of previously conducted exercises. Additional instructor stations may be added to facilitate individual and crew training.

Various embodiments of the invention, therefore, may or may not interface with the instructor station. However, it can be an important component of the overall training system. In embodiments where it is included, it initializes the different VCTS crewman modules, monitors the performance of the trainees, controls the operation of the simulated enemy and friendly forces during the various training exercises, and records all exercise events. In addition, the instructor station supports the conduct of after-action reviews (AARs), wherein

previously conducted exercises are played back as an aid to the instructor's critique of trainee performance. An instructor station can also act as a surrogate driver in the absence of a driver module or any other missing crewmember. If two instructor stations are included, then it is possible to perform the exercise control and monitoring functions with the AAR function simultaneously.

The vehicle crew training system is designed in a modular fashion such that systems may be reconfigured to meet different training needs. Reconfiguration may involve adding, deleting, or changing the mix of crewman modules. Modularity also extends to the design of the crewman modules such that the weapon system and/or the vehicle type may be rapidly changed. For example, a .50 caliber machine gun in use on the HMMWV variant of the vehicle crew training system can be swapped for an MK-19 grenade launcher, a 7.62 mm machine gun, an M249 squad automatic weapon, or a tube-launched optically tracked wire-guided (TOW) missile launcher, for example. Note also that the weapon system can alternatively be a non-lethal weapon that might be used for such actions as crowd control, for instance. Examples of such non-lethal weapons include water cannons, devices for firing tear gas canisters or beanbags, and sound and microwave generators.

An embodiment of the invention can consist of four simulated HMMWV vehicles, each represented by a VCTS with five Crewman Modules. Two instructor stations and simulated radios can be interfaced with such an embodiment of the VCTS through a network. The system provides individual, crew, and collective training to platoons of HMMWV drivers, commanders, gunners and observer/riflemen.

The VCTS is designed to fit into a very constrained space, such as a semi-trailer or a portable shelter. The HMMWV trainer just described fits into two 53-foot semi-trailers.

Another embodiment of the VCTS is a HMMWV training system developed for the U.S. Army National Guard. This system can consist of five simulated HMMWV vehicles, where four of the vehicles are represented by VCTS's consisting of two crewman modules each and the fifth vehicle (external to any VCTS) is represented by an Appended HMMWV containing a driver and gunner position. Simulated radios and an instructor station can also be interfaced to the VCTS. The system provides individual, crew, and collective training to platoons of HMMWV drivers and gunners. The VCTS modules and the instructor station of this embodiment fit in one 53-foot semi-trailer.

Gunner Module

The gunner module embodies a unique approach to weapon system training for simulated ground vehicles. It provides an unrestricted view of the simulated environment to the gunner by means of a head-mounted display (HMD) and a moveable, vehicle-mounted weapon mock-up. The HMD provides a complete spherical (360-degree) field of regard (FOR) to the gunner; as the gunner moves his head, the instantaneous field of view (IFOV) changes in relation to the direction his head is pointed. The weapon mock-up is cradle/pintle-mounted on a 360-degree traverse ring to allow full 360-degree horizontal traverse, as well as the authentic amount of weapon pitch and yaw. External cabling is routed through a slip ring to allow unlimited rotations of the traverse ring. In addition, weapon mock-ups and the weapon software may be easily changed to simulate different vehicle-mounted weapons. Finally, the gunner module is very compact in size, allowing use in restricted environments such as trailers and mobile shelters.

Crewman modules may be of varying fidelity. For example, a lower fidelity desktop version of the gunner module may be used instead of the simulated crew position version described above. "Fidelity" in this context refers to the fidelity or realism of the man-machine interface as experienced by the trainee, i.e., the fidelity of the vehicle and/or weapon controls in terms of numbers of controls and the realism of the controls, the fidelity of visual imagery in terms of field of view, resolution, and scene content, and the fidelity of the physical crew position in terms of the human support structure.

The VCTS architecture supports any mix of varying fidelity crewman modules. Since the lower fidelity desktop versions provide subsets of the capabilities embodied in the simulated crew position versions, all discussions of crewman module will refer to the higher fidelity variants, unless specifically stated otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a diagram illustrating the minimum system configuration of the vehicle crew training system (VCTS), according to an embodiment of the invention.

FIG. **1**B is a diagram illustrating a typical full crew configuration of the VCTS, according to an embodiment of the invention.

FIG. **1**C is a diagram illustrating multiple VCTS systems linked together to support collective training, in accordance with the embodiments of FIGS. **1**A and **1**B; this configuration is representative of a VCTS training system developed for the U.S. Army National Guard.

FIG. **2**A is a diagram showing the major components of a VCTS crewman module, in accordance with the embodiment of FIG. **1**.

FIG. **2**B is a table identifying the types and components that comprise a VCTS crewman module, in accordance with the embodiment of FIG. **2**A.

FIG. **3** is a diagram illustrating the componentized architecture of the VCTS software, in accordance with the embodiments of FIGS. **1** and **2**.

FIG. **4**A is a functional block diagram of the VCTS gunner module hardware in accordance with the embodiments of FIGS. **1**, **2** and **3**.

FIG. **4**B is a functional software diagram of the VCTS gunner module in accordance with the embodiments of FIGS. **1**, **2** and **3**.

FIG. **5**A is a photograph of the overall VCTS gunner module in accordance with the embodiments of FIGS. **1**, **2**, **3** and **4**.

FIG. **5**B is a photograph of the gunner module weapon mock-up, a simulated .50 caliber machine gun in accordance with the embodiments of FIGS. **4** and **5**A.

FIG. **5**C is a photograph of the gunner module traverse ring assembly in accordance with the embodiments of FIGS. **4** and **5**A.

FIG. **5**D is a photograph of the gunner module traverse ring encoder m accordance with the embodiments of FIGS. **4** and **5**A.

FIG. **5**E is a photograph of the gunner module electronics assembly in accordance with the embodiments of FIGS. **4** and **5**A.

FIG. **5**F is a photograph of the gunner module slip ring assembly, head-mounted display and head tracker in accordance with the embodiments of FIGS. **4** and **5**A.

FIG. **6** is a photograph of a lower fidelity desktop variant of a gunnery module, according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Embodiments of the invention are discussed in detail below. In describing embodiments, specific terminology is

employed for the sake of clarity. The invention is not intended to be limited to the specific terminology so-selected. While specific exemplary embodiments are discussed, it should be understood that this is done for illustration purposes only. A person skilled in the relevant art will recognize that other components and configurations can be used without departing from the spirit and scope of the invention.

FIGS. **1**A, **1**B and **1**C illustrate various embodiments of a VCTS system **100** in accordance with the present invention. The system is comprised of at least two crewman modules **102** and **104** connected via a network **110**. Various embodiments currently comprise crewman modules, which can be, for example, a driver module, gunner module, commander module, and observer/rifleman module. Other crewman module types can be supported as needs dictate. These other modules could include, for example, alternate driver modules, crowd-control/riot-control modules, and non-lethal weapon modules. An embodiment of the system that supports a four-man crew is illustrated in FIG. **1**B; this configuration of the system includes a driver module **112**, a gunner module **114**, a commander module **116**, an observer/rifleman module **118**, and network **110**. An instructor station is shown connected to the VCTS. The instructor station **120** provides exercise control, monitoring, and evaluation. An embodiment of the invention that supports collective training is illustrated in FIG. **1**C; four VCTS systems (**130**, **140**, **150**, and **160**), each consisting of a driver module and a gunner module, and linked via network **110**, support four vehicle crews. The four VCTS systems are linked via network **110** to an instructor station **170** and to an appended trainer **180**, which supports a fifth vehicle crew.

FIGS. **2**A and **2**B illustrate the components and characteristics of an embodiment of a VCTS crewman module. Crewman modules are self-contained training devices that contain the necessary hardware and software to support virtual training for a single crewman. In an embodiment of the invention, a crewman module consists of a simulated weapon system **186** (or, in the case of a driver module, a driving system **188**), a display system **190**, a sound system **192**, a computational system **194**, and a crewman station **184**. A simulated weapon system **186** can comprise a weapon mock-up, including all necessary controls such as triggers and arm/safe switches, and the electronics and cabling required to interface it with the computational system **194**. A simulated driving system **188** can comprise a steering wheel, transmission selector, brake and accelerator pedals, and all other necessary controls, electronics and cabling required to drive the vehicle and to interface it with the computational system **194**. The display system **190** consists of the display devices, such as head-mounted displays (HMDs) and liquid crystal display (LCD) panels, and the necessary electronics and cabling required to interface it with the computational system **194**. Sound system **192** consists of amplified speakers and the necessary audio cabling to interface it with the computational system **194**. Weapon and vehicle sounds are broadcast to the trainee via the sound system **192**. The computational system **194** consists of a commercially available PC (or a programmable computing platform of comparable capability, but referred to herein generically as a PC) augmented with standard devices and ports to enable communication with other crewman module hardware components, with other crewman modules, and with external systems such as instructor stations and other vehicle simulators. The crewman station **184** consists of the physical structure that contains and/or supports the trainee, as well as all of the components that comprise a crewman module.

The computational system **194** contains the crewman module software. In an embodiment of the invention, the crewman module software consists of a commercially available operating system and application software. The major functions performed by the application software include simulating vehicle movement, weapon aiming, firing, and impact effects, image generation of visual scenes, interfacing with the various hardware components, and interfacing with other crewman modules and with external systems, such as other vehicle simulators, via the network. The application software in the driver module has the additional functions of calculating collision with other objects in the virtual world and of terrain following by the driver's virtual vehicle.

FIG. **3** illustrates the VCTS application software architecture **300** according to an embodiment of the invention. The software architecture can be an object-oriented design comprised of components, which are encapsulated pieces of software with a defined functional purpose and a defined interface. The purpose of componentizing the application software is to minimize rework and maximize reuse as new vehicles and new weapons are incorporated into the VCTS design.

Software components are categorized as either being application-specific or reusable. If the latter, they are placed into a library of reusable components. In an embodiment of the invention, one or more application specific components **310** generally links to one or more reusable components **320** to perform a given function. A collection of drivers and application program interfaces (APIs) **330** may also be included with the application software to interface with hardware **340**. Drivers and AP is **330** include drivers for the video and data acquisition cards housed in the PC, as well as network, joystick and sound drivers and the API for the visual software. Underlying the components, drivers and APIs is the real-time executive software **350** that provides the universal means for components, drivers and API's to communicate via messages, events, and data reflection through its interface. The real-time executive software **350** can also be componentized.

FIG. **4**A is a functional hardware diagram of an embodiment of the gunner module, and FIG. **4**B is a functional software diagram of this embodiment of the gunner module. The illustrated weapon system is comprised of weapon mock-up **402**, traverse ring encoder **404**, calibration button **406**, and an interface device **408**. The weapon mock-up **402**, in one embodiment of the invention, is a simulated .50 caliber machine gun. The position, pitch and yaw of the simulated weapon are measured continuously, and fed back to PC **407** via the interface device **408**. One example of such an interface device **408** is a buffer board, as shown in FIG. **4**A. A calibration signal is fed back to the PC **407** via the interface device **408** when the trainee pushes the corresponding button **406**. The interface device **408** applies signal conditioning to the incoming signals and sends the data to a data acquisition (DAQ) card **410** in the PC **407**. Referring to FIG. **4**B, the weapon I/O software **431** in the PC **407** inputs the data **441** from the DAQ Card **410**, formats it, and outputs the formatted weapon data **442** to the weapon simulation software **432**. Weapon data **442** is received continuously and includes weapon position, pitch, yaw, and trigger pull. The calibration signal is sent only during the weapon calibration process. The weapon simulation software **432** computes a trajectory for the bullets and outputs projectile position data **444** to the network software **434**. The weapon simulation software **432** receives own-vehicle state data **443** continuously from the network software **434**. This data is used to compute the position of the weapon in the virtual environment.

In the embodiment illustrated of FIG. **4**A, the display system **190** is comprised of a head-mounted display (HMD) **412** with an attached head tracker (HT) receiver **414**, an HT transmitter **416** mounted above the gunner position and the HMD and HT interface electronics (**418** and **420**, respectively). In addition, an LCD panel is provided to serve as a video repeater **422** for the benefit of the instructor. In this embodiment of the invention, an acoustic HT system senses the position and attitude of the HMD **412**, and continuously feeds the data to the PC **407** via the HMD/HT data interface. Referring to FIG. **4**B, HT data **446** is continuously input to visual I/O software **460** where it is formatted and then output (see **448**) to visual simulation software **465**. The visual simulation software **465** uses the formatted HT data **448** to determine the position and look angle of the head relative to the visual scene that is displayed to the trainee wearing the HMD **412**. In an embodiment of the invention, the visual simulation software **465** also performs the following functions:

- Rendering of the visual scene according to the HT-supplied look angle (in data **448**) and according to own-vehicle state data **449** received from the network software **434**;
- Full color, perspectively correct, anti-aliased and textured image generation;
- Imagery affected by atmospheric and weather effects;
- Night vision simulation;
- Rendering of other vehicles according to vehicle state data **449** received from the network software **434**;
- Input of own.-weapon projectile data **444** and subsequent impact detection processing;
- Weapon effect generation and rendering based on own-weapon projectile impact detection;
- Weapon effect generation and rendering based on weapon impact data (in data **444**) received from the network software **434**;
- Output of own-vehicle weapon impact and collision data **450** to the network software **434**;
- Collision detection of the own-vehicle with other objects in the virtual world;
- Terrain following by the own-vehicle; and
- Output of video **447** to the visual **110** software **460**.

The visual I/O software **460** formats the video and sends it to the video card **424** in the PC **407** (see FIG. **4**A); the video **445** is then output to the display system **190** as standard VGA video.

In the illustrated embodiment, the network software **434** sends and receives data **451** to and from the network **110**. Data sent to the network **110** includes projectile state data received from the weapon simulation software **465**, and weapon impact and collision data received from the visual simulation software **465**. Data received from the network **110** includes own-vehicle state data plus the state of all other vehicles and projectiles that are active in the virtual environment.

In the embodiment of the invention shown in FIG. **4**A, a sound system **192** generates aural cues synchronized with and representative of actions and events in the virtual environment. Sounds can caused by, for example, own vehicle and other vehicle movements, own weapon and other weapon firing, weapon impacts and explosions caused by own weapons or other weapons, and could even include environmental "noise" such as crowd noise.

The sound system **192** includes amplified speakers **426** that receive audio **452** from the PC **407** via standard audio cables in an embodiment of the invention. The sound I/O software **470** is a sound driver that receives the sound data **453** from sound simulation software **475** and formats it for use by the standard sound hardware in the PC **407**. The sound simulation software **475** creates sounds based on weapon and vehicle state data **454** that is received from the network software **434**. Sound files representing different battlefield sounds are created off-line and then stored in a sound file library; during real-time, the sound simulation software **475** accesses the appropriate sound files and weights them appropriately to create aural cues for the trainee.

In an embodiment of the invention, the computational system **194** consists of a commercially available PC equipped with 2 GB of main memory and a Pentium 4® CPU; Windows XP® maybe used as the operating system. In this embodiment, the DAQ **410** card is a commercially available PCI card that supports both analog and digital signals. The video card **424** may be a commercially available PCI graphics card.

FIG. **5**A is a photograph illustrating the overall mechanical design of a gunner module **500**, according to an embodiment of the invention. The gunner module **500** is built on a gunner station **505**, which is a large aluminum box with a large circular hole cut in the top panel. A traverse ring **510** is fastened to the top of the box. The traverse ring **510** consists of a pallet carousel modified for use with the gunner module **500**. An electronics assembly **515**, an HMD/HT support structure **520**, and a weapon mock-up **525** are attached to the traverse ring **510** such that they move with the traverse ring **510** in response to trainee pressure. A slip ring support structure **530** is attached to the gunner station **505**, such that it remains fixed in space regardless of traverse ring rotation. A slip ring **535** and a video repeater **540** are attached to this support structure. Each of these items is described in more detail in the following paragraphs.

FIG. **5**B is a photograph illustrating an embodiment of the mechanical design of the weapon mock-up **525**, which in this embodiment of the invention is a .50 caliber machine gun. A mounting base **542** for the simulated weapon is attached to the traverse ring **510**, such that the simulated weapon moves when the traverse ring **510** moves. The main body of the gun is attached to the mounting base **542** via a cradle/PINTLE mount **544** that permits simultaneous pitch and yaw aiming of the simulated weapon. Pitch and yaw sensors **546** and **548** built into the cradle/PINTLE mount **544** consist of potentiometers that change voltage in direct proportion to the rotation of the simulated weapon in each axis. Attached to the back end of the main body of the simulated weapon are hand grips **550** and a trigger **552** that are used by the trainee to aim and fire the weapon. A charging handle **554** is included in the mechanical design, but it is not functional in the illustrated embodiment. A counterweight **556** is attached to the front end of the main body of the simulated weapon in order to provide a realistic heft and balance to the trainee.

FIG. **5**C is a photograph illustrating the mechanical design of the traverse ring **510** and attached components, according to an embodiment of the invention. As shown, the traverse ring **510** is a circular carousel attached to the top panel of the gunner station **505**. It rotates freely in both directions in response to trainee pressure applied to a gunner back rest **558**. A cover **560** is attached to the traverse ring **510** to simulate the space constraints of a HMMWV-mounted .50 caliber machine gun; it is also used to mount the calibration button **562** and, on the underside of the cover **560**, the traverse ring encoder (not shown). A weapon mock-up mounting base **564** and a bustle plate **566** are also attached to the traverse ring **510**, such that all of the components mounted to these support surfaces move with the traverse ring **510**.

FIG. **5**D is a photograph of an embodiment of the traverse ring optical encoder **568** which, as mentioned above, is attached to the underside of the traverse ring cover **560**. A sensing wheel **570** is a metal wheel with a rubber o-ring that

is positioned against the inside of the traverse ring **510**, such that the wheel moves when the traverse ring **510** moves. Optical encoder **568** senses the rotation and converts it to an eight-bit digital signal. This signal is routed back to the data acquisition card in the PC via the interface device.

FIG. **5**E is a photograph illustrating the mechanical design of the electronics assembly **515** of the gunner module **500**, according to an embodiment of the invention. This assembly is attached to the bustle plate **566** such that the entire electronics assembly **515** moves with the traverse ring **510**. The components that comprise the electronics assembly **515** can include the following:

- A commercially available PC with DAQ and video cards, **572**;
- Amplified speakers **574**;
- HMD interface electronics **576**;
- Head tracker (HT) interface electronics **578**; and
- Enclosure containing power strips and the interface device, **580**.

FIG. **5**F is a photograph illustrating the mechanical design of the superstructure of the gunner module **500**, according to an embodiment of the invention. The HMD/HT support structure **520** is attached to the bustle plate **566** which, in turn, is attached to the traverse ring **510**, such that the HMD/HT support structure **520** and components attached to it move with the traverse ring **510**. The HMD **582** can be hung on the HMD/HT support structure **520** when not in use. In the illustrated embodiment, the HMD **582** is a commercially available display device that provides a view of the virtual environment to the trainee directly in front of his eyes. Standard VGA video is fed to the HMD **582**. A sensor is attached to the top of the HMD **582**; this is the HT Receiver **584**. The HT receiver **584** works in concert with an HT transmitter **586**, which is attached to a mounting plate on the top of the HMD/HT support structure **520**. For this embodiment of the invention, an acoustic HT system is employed; acoustic signals are transmitted by the HT transmitter **586** and received by the HT receiver **584**. As the trainee head (and therefore the HMD **582**) moves, the time required for the acoustic signals to travel the distance between the HT transmitter **586** and the HT receiver **584** continuously changes in direct proportion to the distance between the transmitting and receiving devices. The visual simulation software computes the position and orientation of the HMD **582** (and therefore the trainee's head) based on these signals.

For this embodiment of the invention, the slip ring **535** is attached to the slip ring support structure **530**, which is attached to the main body of the gunner station **505**. Therefore, the slip ring **535** stays fixed in space as the traverse ring **510** moves. The slip ring **535** is a commercially available device that routes wires through the slip ring **535** to the HMD/HT support structure **520**. As the traverse ring **510** moves, slip ring cabling **588** moves in a circular motion around the slip ring **535**, but cable connections are maintained. Since most of the electronics are mounted on the bustle plate **566** or otherwise attached to the traverse ring **510**, only a few wires are passed over the slip ring cabling **588**. They include:

- Ethernet cabling for the ethernet network that connects the gunner module **500** to other crewman modules or to external systems;
- VGA video cabling for the video repeater **540** attached to the slip ring support structure **530**; and
- Power cabling for the various electronic devices attached to the traverse ring **510**.

In another embodiment of the invention, the slip ring could be integrated into the traverse ring.

Note that, in addition to the HT apparatus discussed above, other mechanisms could be used to track the position and/or orientation of the head of the gunner trainee. Examples include inertial head trackers and eye trackers, both of which are known in the art.

FIG. **6** is a photograph of an embodiment of a lower fidelity desktop variant **600** of the gunner module. This version of the gunner module provides all of the functionality of the higher fidelity gunner module described above. Differences include those relating to the fidelity of the device. For example:

- The gunner simulates moving a traverse ring using foot pedals **610** and software that moves a weapon mock-up **620** around the simulated ring; the imagery displayed to the gunner on an HMD **630** presents the view that the gunner would see if he moved the traverse ring with his feet and back as he would on the higher fidelity variant of the gunner module.
- A lower fidelity HMD **630** is used with reduced resolution and with angular tracking only, i.e., only in the direction that the Gunner's head is pointed is sensed by the head tracker.

While various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail may be made therein without departing from the spirit and the scope of the invention.

What is claimed is:

1. A computer-based simulation system for training vehicle crew members for operation of a multi-crew member vehicle, the simulation system comprising:

- a plurality of self-contained modules, configured to simulate the operation of the multi-crew member vehicle, and further configured to be connected to one another by a network, wherein each module comprises:
- a self-contained physical structure configured to provide a position for only an individual crew member, dedicated to a simulation of a single distinct crew station of the multi-crew member vehicle, and configured to operate while geographically separated from at least one other of the plurality of self-contained modules; and
- a mechanical mockup within the self-contained physical structure, configured to dedicate the module to the simulation of the single distinct crew station.

2. The computer-based simulation system of claim **1**, wherein the position is configured to support a virtual dismounting of a trainee such that the trainee can exit the simulated single distinct crew station of the multi-crew-member vehicle while maintaining the ability to interact with a virtual environment from the vantage point of a dismounted position.

3. The computer-based simulation system of claim **1**, wherein the self-contained modules are reconfigurable.

4. The computer-based simulation system of claim **3**, wherein reconfigurable involves adding, deleting, or changing the mix of self-contained modules.

5. The computer-based simulation system of claim **3**, wherein the self-contained modules are reconfigurable to simulate multiple types of vehicles.

6. The computer-based simulation system of claim **3**, wherein the self-contained modules are reconfigurable to simulate multiple types of weapons.

7. The computer-based simulation system of claim **1**, further comprising an instructor station.

8. The computer-based simulation system of claim **7**, wherein the instructor station is configured to function as a replacement of one of the plurality of self-contained crewman modules.

9. The computer-based simulation system of claim 1, wherein the simulation of the single distinct crew station comprises presenting a visual imagery to a vehicle crew member.

10. The computer-based simulation system of claim 9, wherein the visual imagery presented to the vehicle crew member is configured at multiple levels of fidelity.

11. The computer-based simulation system of claim 10, wherein a number of controls presented to the vehicle crew member is proportional to the level of fidelity.

12. The computer-based simulation system of claim 10, wherein a lower fidelity level presents a subset of capabilities as compared to a higher level of fidelity.

13. The computer-based simulation system of claim 10, wherein a lower fidelity level presents a lower level of visual imagery in terms of field of view, resolution, and scene content.

14. A self-contained crewman module for use in a simulation system simulating an operation of a multi-crew member vehicle, comprising:

first and second self-contained physical structures, wherein the first and second self-contained physical structures are each dedicated to a simulation of a single distinct crew station of a multi-crew member vehicle, wherein the first and second self-contained physical structures are geographically separated and are configured to be connected to each other by a network; and

a mechanical mockup within each of the first and second self-contained physical structures, configured for the simulation of the corresponding single distinct crew station.

15. The self-contained crewman module of claim 14, wherein the position is configured to support a virtual dismounting of a trainee such that the trainee can exit the simulated multi-crew-member vehicle while maintaining the ability to interact with a virtual environment from the vantage point of a dismounted position.

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